Rocky Mountains Southwest Great Plains

Research Note RM-389

August 1980

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Woody Fuel Particle Size and Specific Gravity of Southwestern Tree Species

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Average squared diameters and specific gravities were determined for eight species of forest trees in Arizona and New Mexico. These figures are used to help estimate weights and volumes of dead, down forest fuels using the planar intersect method. Values in the 0- to 0.25-inch, 0.25- to 1-inch, and 1- to 3-inch-diameter size classes are given for natural and activity-generated (slash) fuels.

Keywords: fuel inventory, slash residues, forest fires

Introduction

The use of the planar intersect method for inventorying downed woody material (Van Wagner 1968; Brown 1971, 1974; Brown and Roussopoulos 1974) is a widely accepted means of determining weight, volume, and depths of forest residues. The technique is used by many state and federal agencies to evaluate both natural debris and activity-generated residues (fuels) for purposes of fuel and fire research and management planning, and to assess the utilization potential for these residue materials. In addition, the method provides an opportunity to use fuel data to predict fire behavior.

To effectively use the planar intersect method for fuel evaluation, certain physical characterictics must be known about the woody material being measured. These characteristics may vary among tree species, within and among size classes, and among regions of the country for the same species. Different stages of decay represent another variable. Most important of these are the values that represent the average squared diameter ($\overline{d^2}$) and specific gravities (s) for the species and size class of material being estimated. Anderson (1978) simplified field calculations of the planar intersect sampling technique by providing graphic aids. Brown and Roussopoulos (1974) included common Intermountain West and North Central tree species. Roussopoulos and Johnson (1973) established these factors for slash fuels of several Lake State's tree species. Bevins (1978) has established a $\overline{d^2}$ value for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) slash fuels in Washington. Ryan and Pickford (1978) defined $\overline{d^2}$ and s values for natural fuels of seven tree species common to the Blue Mountains of Oregon and Washington.

The purpose of the work described here was to establish $\overline{d^2}$ and s values for standard dead, down forest fuel size classes of southwestern tree species so that the planar intersect method could be more readily adapted to Southwest conditions. Anderson (1978) points out that estimates of fuel loads can be improved by assigning specific gravities for the timber type in which the inventory is being made. He also suggests adjustments for average squared diameter be made, when available, at least for computer processing of fuel data.

Methods

Measurements were made primarily in Arizona and New Mexico to establish the $\overline{d^2}$ and s factors in 26 stands

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on 8 different forests. More than 4,300 diameter measurements were taken on 8 tree species. Specific gravities (s) were determined on approximately one-half of the above samples. Random transects were established, and diameter measurements were made to the nearest 0.001 inch in three size class categories common to the planar intersect inventory, using a machinist's micrometer. Slash measurements were made in recently cut material. Every second sample measured was collected and returned to the laboratory for specific gravity determination. Specific gravity was determined by weighing the displacement of an air-dried sample in mercury (Hg) and applying this value plus the sample's oven dry (OD) weight using the following formula:

$$s = 13.5939 \frac{W_{OD}}{W_{Hg}}$$

where:

s = sample specific gravity
13.5939 = specific gravity of mercury
W_{OD} = oven dry weight of sample (grams)
W_{Hg} = weight of the volume of mercury displaced by the sample (grams)

Results and Discussion

Table 1 shows the average squared diameter findings for both natural and activity-generated (slash) fuel for species commonly found in the southwestern United States. Specific gravities are summarized in table 2. Tables 3 and 4 illustrate the $\overline{d^2}$ and s differences, respectively, between common species found in the Intermountain West (Brown and Roussopoulos 1974), the Blue Mountains of Oregon and Washington (Ryan and Pickford 1978), and the Southwest. No clear pattern of differences emerges from the summary of either the diameters or the specific gravities. Diameter differences range from 0% to 62%. Specific gravity ranges from 2% to 53%.

The effect of the combined $\overline{d^2}$ and s differences in predicted fuel loadings would result in four cases being heavier using Brown's (1974) figures, and eight cases being lighter. Using the eight common cases of Ryan and Pickford (1978), two cases would produce heavier loads and six cases lighter.

Table 1.—Average squared diameters ($\overline{d^2}$) for natural and slash fuel found in the southwestern United States

Diameter size class	Natural				Slash			
	Species[1]	$\overline{d^2}$	Standard deviation	Sample size	Species[1]	$\overline{d^2}$	Standard deviation	Sample size
inches		*square inches*		*number*		*square inches*		*number*
0-0.25	PP	0.0378	0.0139	370	PP	0.0471	0.0107	60
	AS	.0275	.0151	110	WF	.0319	.0138	60
	OA	.0217	.0156	80	WP	.0284	.0105	60
	WP	.0216	.0121	100	DF	.0239	.0178	60
	AF	.0191	.0156	60	AS	.0236	.0114	60
	S	.0142	.0136	180	AF	.0234	.0139	60
	DF	.0132	.0151	120	S	.0172	.0092	60
0.25-1	DF	.3718	.2628	119	DF	.3228	.2309	60
	OA	.3568	.2481	80	AF	.2947	.2430	60
	S	.3450	.2577	180	AS	.2624	.1770	60
	AS	.3226	.2378	110	PP	.2467	.1988	60
	WP	.2421	.2072	100	WF	.2432	.2523	60
	PP	.2366	.2180	369	WP	.2171	.1891	60
	AF	.2295	.1528	60	S	.2137	.1624	60
1-3	AS	3.468	2.457	110	PP	3.574	2.231	60
	DF	3.142	1.957	120	WF	2.759	1.844	60
	PP	2.967	1.827	371	DF	2.508	1.170	60
	OA	2.870	1.760	80	AS	2.208	1.258	60
	AF	2.411	1.910	60	WP	2.197	1.231	60
	S	2.237	1.180	180	S	1.915	0.550	60
	WP	2.208	1.392	100	AF	1.895	0.523	60

[1]*Species refers to those that are found in the Southwestern Region: PP = ponderosa pine (*Pinus ponderosa *Laws.); AS = aspen (*Populus tremuloides *Michx.); DF = Douglas-fir (*Pseudotsuga menziesii *var.* glauca *(Beissn.) Franco); S = Engelmann spruce (*Picea engelmanii *Parry) and blue spruce (*Picea pungens *Engelm.); AF = corkbark fir (*Abies lasiocarpa *var.* arizonica *(Merriam) Lemm.); WP = southwestern white pine (*Pinus strobiformis *Engelm.); WF = white fir (*Abies concolor *(Gord. & Glend.) Lindl.); and OA = Gambel oak (*Quercus gambelii *Nutt.)*

Table 2.—Specific gravities (s) for natural and slash fuel found in the southwestern United States

Diameter size class	Natural				Slash			
	Species[1]	s	Standard deviation	Sample size	Species[1]	s	Standard deviation	Sample size
inches				*number*				*number*
0-0.25	OA	0.582	0.090	32	AS	0.579	0.072	24
	DF	.526	.077	20	WP	.551	.048	24
	S	.480	.121	116	WF	.551	.236	24
	PP	.463	.104	140	PP	.540	.072	26
	AS	.422	.090	109	DF	.463	.131	22
	AF	.398	.142	58	S	.457	.152	54
	WP	.373	.107	30	AF	.356	.084	18
0.25-1	OA	.546	.109	35	WF	.596	.281	26
	DF	.534	.068	20	AS	.584	.040	23
	S	.519	.076	170	WP	.565	.076	24
	AF	.472	.100	54	DF	.555	.048	24
	WP	.466	.150	44	PP	.543	.050	24
	PP	.464	.062	139	AF	.478	.046	24
	AS	.404	.111	134	S	.471	.137	53
1-3	OA	.635	.119	70	WF	.541	.069	24
	DF	.574	.139	20	AS	.526	.052	21
	S	.519	.124	87	WP	.524	.068	24
	WP	.458	.056	37	AF	.523	.065	25
	AF	.428	.069	57	DF	.505	.049	25
	PP	.392	.078	85	PP	.502	.057	24
	AS	.390	.011	134	S	.472	.076	54

[1]*Species refers to those that are found in the Southwestern Region: PP = ponderosa pine (*Pinus ponderosa *Laws.); AS = aspen (*Populus tremuloides *Michx.); DF = Douglas-fir (*Pseudotsuga menziesii *var.* glauca *(Beissn.) Franco); S = Engelmann spruce (*Picea engelmanii *Parry) and blue spruce (*Picea pungens *Engelm.); AF = corkbark fir (*Abies lasiocarpa *var.* arizonica *(Merriam) Lemm.); WP = southwestern white pine (*Pinus strobiformis *Engelm.); WF = white fir (*Abies concolor *(Gord. & Glend.) Lindl.); and OA = Gambel oak (*Quercus gambelii *Nutt.)*

Table 3.—Natural fuel differences of average squared diameters ($\overline{d^2}$) for tree species common to the Southwest, the Intermountain West, and the Blue Mountains of Washington and Oregon

Species	Diameter size class	Average squared diameters ($\overline{d^2}$)				
		Southwest	Intermountain West[1]	Difference[2]	Blue Mountains[3]	Difference[4]
	inches	*square inches*	*square inches*	*percent*	*square inches*	*percent*
Ponderosa pine	0-0.25	0.0378	0.0342	+10	0.0356	+6
	0.25-1	.237	.238	0	.262	−10
	1-3	2.97	3.12	−5	—	—
Douglas-fir	0-0.25	.0132	.0122	+8	0.0143	−8
	0.25-1	.372	.304	+22	.230	+62
	1-3	3.14	2.87	+9	—	—
Spruce	0-0.25	.0142	.0122	+16	0.0192	−26
	0.25-1	.345	.304	+14	.280	+23
	1-3	2.24	2.87	−22	—	—
Subalpine fir (corkbark fir)	0-0.25	.0191	.0122	+57	0.0167	+14
	0.25-1	.230	.304	−24	.208	+11
	1-3	2.41	3.12	−23	—	—

[1]*Brown (1974), table 2*

[2]$\dfrac{\text{Southwest — Intermountain}}{\text{Intermountain}} \times 100$

[3]*Ryan and Pickford (1978), table 2*

[4]$\dfrac{\text{Southwest — Blue Mountains}}{\text{Blue Mountains}} \times 100$

Table 4.—Natural fuel differences of specific gravities (s) for tree species common to the Southwest, the Intermountain West, and the Blue Mountains of Washington and Oregon

Species	Diameter size class	Specific gravities (s)				
		Southwest	Intermountain West[1]	Difference[2]	Blue Mountains[3]	Difference[4]
	inches			*percent*		*percent*
Ponderosa pine	0-0.25	0.463	0.41	+12	0.41	+12
	0.25-1	.464	.51	−10	.51	−10
	1-3	.392	[5].40	−2	—	—
Douglas-fir	0-0.25	.526	.55	−4	.61	−13
	0.25-1	.534	.43	+23	.62	−14
	1-3	.574	[5].40	+44	—	—
Spruce	0-0.25	.480	.34	+41	.34	+41
	0.25-1	.519	.34	+53	.34	+53
	1-3	.519	[5].40	+30	—	—
Subalpine fir (corkbark fir)	0-0.25	.398	.41	−2	.41	−2
	0.25-1	.472	.40	+18	.40	+18
	1-3	.428	[5].40	+7	—	—

[1]Brown (1974), table 4

[2] $\frac{\text{Southwest — Intermountain}}{\text{Intermountain}} \times 100$

[3]Ryan and Pickford (1978), table 2

[4] $\frac{\text{Southwest — Blue Mountains}}{\text{Blue Mountains}} \times 100$

[5]Brown (1974), p. 17

Conclusions

Dead, down forest fuel loadings in the Southwest can be determined by the computer program DOFUINV[2] using the figures presented in tables 1 and 2. Brown (1974) illustrates how calculations are done manually. Appropriate $\overline{d^2}$ and s can be used from the tables 1 and 2. Greater than 3-inch-diameter, sound material specific gravities can be found in U.S. Department of Agriculture, Forest Products Laboratory (1974) or U.S. Department of Agriculture, Forest Service (1973). Rotten material greater than 3-inch diameter has a tremendous range of specific gravities. Brown's (1974) figure of 0.30 is adequate to use for all species.

Although the data for this note were gathered in Arizona and New Mexico, it is reasonable to assume the $\overline{d^2}$ and s factors would work equally well for southern Utah and southwestern Colorado.

[2]DOFUINV is a computer program taken from DFINV (NFFL program) and modified for use in southwestern forest stands. It is designed for use on an 1100 Univac computer. A copy of the program can be requested from: Fuel Management Project, USDA Forest Service, Forestry Sciences Laboratory, Arizona State University Campus, Tempe, AZ 85281.

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